§11. Efficient Heating of High Density Plasmas Up to Cut-off Density of 106.4 GHz ECH Power on CHS

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Extending the CHS plasma parameter to high density and high temperature regime is the most important objective of application of 106.4 GHz power. In this report probability of electron heating at higher density up to the limit of cut-off is described. For the waves with frequency of 53.2 GHz, theoretical cut-off density for B=0.95 T by 2nd harmonic X-mode and for B=1.9 T by fundamental O-mode are 1.8 and 3.5×10^{19} /m^3, respectively. Applying the frequency of 106.4 GHz, the cut-off density for B=1.9 T by 2nd harmonic X-mode increases up to 7×10^{19} /m^3.

Plasma heating at higher density than cut-off density of 53.2 GHz is experimentally demonstrated. In the experiment, 106.4 GHz power in X-mode aiming at the magnetic axis is injected to B_{ax}=1.9 T magnetic field to generate plasma and the initial plasma is heated and sustained by NB power of about 700 kW. To the high density NB-sustained plasmas, second ECH pulses are injected from 60 ms to 91 ms. 53.2 GHz power of 120 kW in O-mode is also applied with the same time sequence.

The density of target plasma is scanned by adjusting gas puffing during the discharges. Representative time traces of line averaged electron density measured with HCN laser interferometer are plotted in Fig. 1. Injection timings of ECH pulses are denoted by hatched regions. When the density is kept low, effect of density clumping by ECH is clear while with higher density the density keeps increasing. The discharge #120554 is terminated immediately at the end of 2nd ECH pulses though the NB power is applied until 93 ms.

Figure 2 shows the increment of stored energy by 2nd ECH pulses, and the increment divided by the density and stored energy at the starting time of the 2nd pulses as functions of the density at that time. With the averaged density higher than 5.6×10^{19} /m^3, the effect of the 2nd ECH pulses degrades and it vanishes at over 6.8×10^{19} /m^3.

The evolution of stored energy is plotted as a function of averaged density in the discharge #120540 in Fig. 3. The data during the 2nd ECH pulses are stated in the figure. The gradient of the plot is slightly increased at first by the application of ECH pulses, that is, electron temperature is increased. However when the density reaches at 6.8×10^{19} /m^3, the stored energy starts decreasing though the ECH and NB powers are still applied.

Those experimental results clearly demonstrate that the 106.4 GHz power applied to CHS works very well for high density plasma heating up to its theoretical limitation by 2nd harmonic X-mode cut-off.

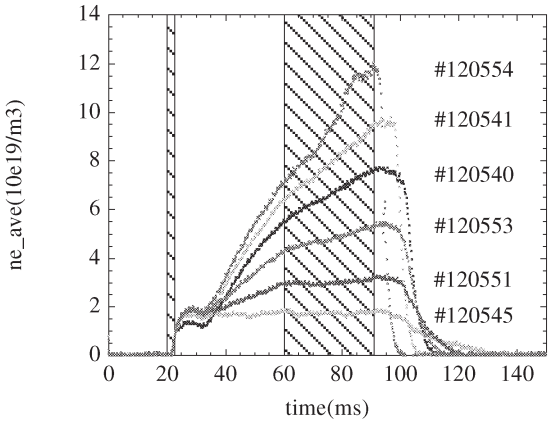

Fig. 1. Time traces of line averaged electron density measured with HCN laser interferometer.

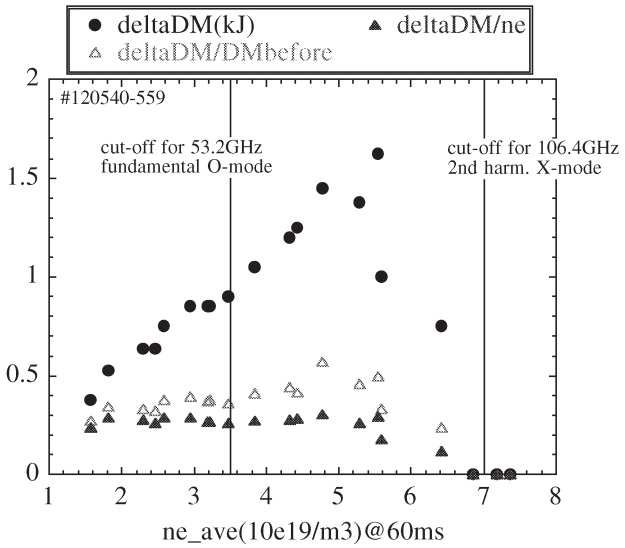

Fig. 2. Increment of stored energy by 2nd ECH pulses and that divided by density and stored energy.

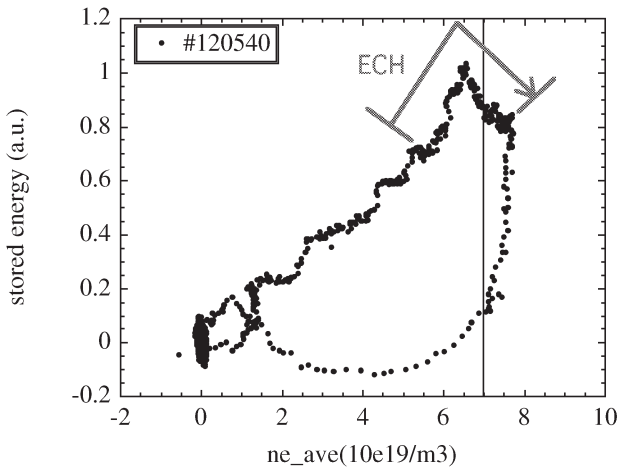

Fig. 3. The evolution of stored energy plotted as a function of averaged density in the discharge #120540.